Low cost carrier independent telecommunications infrastructure

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Abstract— Despite the impressive success in both wireless and fiber optics telecommunications deployment achieved in recent years, there are still many regions that are not adequately served by traditional telecommunications service providers because of the insufficient rate of return of the necessary investment in a reasonable time.

In those places, broadband wireless communication can be built directly by small organizations taking advantage of the availability of low cost wireless routers that can be installed by persons with limited training, aided by training materials developed specifically for this purpose, and by examples of deployments in different scenarios.

This paper will review some of the efforts to deploy low cost broadband wireless systems in many countries, and the production of training materials to empower individuals to design, install and maintain their own communication infrastructure.

The application area span from providing telecommunication services in sparsely populated areas not currently served, to the installation of broadband wireless networks for universities and other organizations at much lower cost than what traditional providers charge.

Keywords—low cost wireless; community wireless networks; long distance wireless;

I. Introduction

An adequate telecommunications service is essential to provide education, health and entertainment services, as well as to enhance the productivity of people everywhere.

Wireless is the least expensive way to provide telecommunications in rural areas, and the availability of unlicensed spectrum coupled with low cost radios provides an affordable solution that has been deployed in several scenarios as described in [1].

For developing countries, wireless allows leapfrogging over the traditional telecommunications infrastructure. This has been proved in many countries of Africa and Latin America, where the number of mobile phones has greatly surpassed the number of land lines.

Although fiber optics offers much greater bandwidth, and satellite systems are unsurpassed for unidirectional broadcast services, neither can compete with land-based radio from a cost perspective for two-way applications.

Furthermore, both fiber optic and satellite systems require large up-front investments and considerable expertise to properly maintain them, which means that they can only be deployed by large organizations with deep pockets that can wait several years before recovering their investments. Terrestrial microwave systems, on the other hand, are less capital intensive, the investment is gradual as the network grow over time, and can be deployed by smaller organizations and even local communities.

To fully reap the benefits of this technology, it is paramount to expose it to the broadest possible audience, and to provide capacity building to non-specialists. That is why several organizations have made considerable efforts to disseminate these ideas.

II. Capacity Building

Since 1992, the ICTP (International Centre for Theoretical Physics) in Italy [2], and its off-spring, EsLaRed (Escuela Latinoamericana de Redes) [3], in Venezuela, have been providing training in wireless data communications, and over the years other organizations like NSRC (Network Startup Resource Center) [4] at the University of Oregon and APC (Association for Progressive Communications) [5], have made their own efforts to develop training materials and conduct training workshops in many countries, wile institutions like IDRC (International Development Research Centre) [6], UNESCO and the Internet Society have made significant financial contributions to this end.

The book "Wireless Networking for Developing Countries" has met with a great success; the on-line version has been downloaded more than 2 million times and there are

The main sponsors for this work are ICTP and NSRC.

translations in Spanish, French, Arabic, Portuguese and Indonesian [7].

A set of lectures meant to facilitate the conduction of wireless training workshops by non specialist has been produced, the "ICTP-UNESCO Wireless Training Kit" [8], which comprises exercises, lecture slides with notes and recommended hardware to perform basic experiments. These materials are freely available in English, Spanish and French, and have already been used in locally organized workshops in Rwanda and Senegal, with support from ITU (International Telecommunication Union) and in Venezuela, Colombia, Bolivia, Guatemala and Ecuador.

The technology is constantly evolving, so the new equipment that becomes available must be tested to ascertain its capabilities in field trials before deployment. These trials and experiments provide new inputs for the training materials which must be frequently updated to take advantage of the state of the art of the hardware and software required to provide cost effective communication services.

III. High Altitude Links

Since 2001, Fundacite Mérida has operated a 70 km link between Pico Espejo and Canagua, from a 4765 m high site to another at 2000 m above sea level in the Venezuelan Andes. This showed that with a clear line of sight, long range could be attained, spurring the interest to investigate the limits of this technology.

Professor Gerd Hochschild from Bremen University lead a team that in 2002 installed a microwave atmospheric Laboratory in Merida [9], and was looking for a reliable system to transfer the collected data to the University of los Andes. The requirement was that the radio link would withstand the harsh environment of the 4765 meter above sea level site and that the operation would avoid the 2.4 GHz band, since this was the IF frequency of the 270 GHz receiver they were using.

Accordingly, we installed a 15 km link from Pico Espejo to the university in Merida in 2002 which has been operating ever since.

Encouraged by this result, in April 2006 we conducted an experiment over a 280 km path between one site at 4300 m and another at 125 m, taking advantage of the very flat terrain of the Venezuelan plains. The transmission speed was very limited, due to the limitations of the CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance) media access control employed in the unmodified WiFi routers used, with an output power of 100 mW, but a year later we were able to do another experiment in the same region, using TDMA (Time Division Multiple Access) routers, which showed a throughput of 6 Mbit/s over a 382 km path, given that this time we had an elevation of 4300 m at one end and 1500 m at the other end, enabling complete clearance of the first Fresnel Zone at 2.4 GHz. In the profile of this link shown in figure 1 it is quite evident the effect of the earth curvature over this very long link, but the Fresnel zone was cleared thanks to the great elevation of the end points and the flatness of the terrain in between [1].

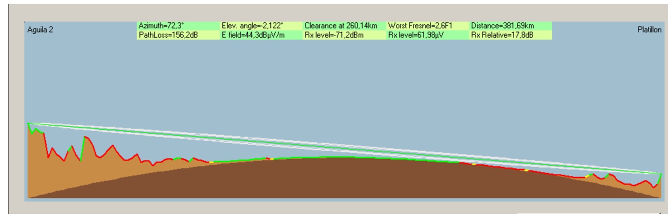

Figure 1. Profile of the 382 km transmission experiment at 2.4 GHz between Pico del Aguila and Platillon, Venezuela. The earth curvature (dark brown) is quite evident, but the terrain is flat in the critical points and elevated in the extremes, allowing for ample clearance of the first Fresnel Zone.

Several other experiments were later performed in Italy over distances of 100 and 130 km, with different radios, both at 2.4 GHz and at 5 GHz with encouraging results [10].

It is worth noting that the performance attained on this long distance links shows the viability of modified WiFi as a low cost alternative to WiMAX for backhaul applications. Similar work performed by professor Trinchero in Europe [11] confirms the feasibility of links up to 300 km long using low cost WiFi radios with modified media access control. Furthermore, the capability of WiFi for point-to-multipoint and even mesh topologies have been demonstrated [12], [13], which makes it the technology of choice for community-based networks for its low cost and limited installation skill requirements, especially in rural areas where the interference issue of unlicensed bands is less severe.

IV. Deployment Examples

In 1997 Fundacite Merida began the installation of a wireless data network that had been planned at the Communications Lab of Universidad de los Andes headed by Prof. Pietrosemoli [14] in Venezuela. This network provided Internet access to schools, hospitals, community centers and government offices. Initially it made use of packet radio technologies but soon migrated to broadband, and won the 1998 Super Quest award as the best remote access network presented in Atlanta, Georgia. The longest link profile is shown in figure 2.

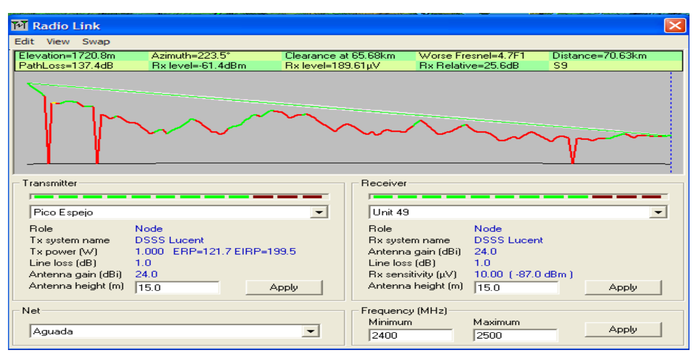

Figure 2. Profile of the 70 km link between Pico Espejo and Canagua, Merida State, Venezuela.

A. *Galapagos Inter-Islands Broadband Network*

Figure 3. Radial links from the hub at Cerro Croker to the islands of Baltra (north), San Cristobal (east) and Isabela (west) and the town of Puerto Ayora (south) in the same island of Santa Cruz.

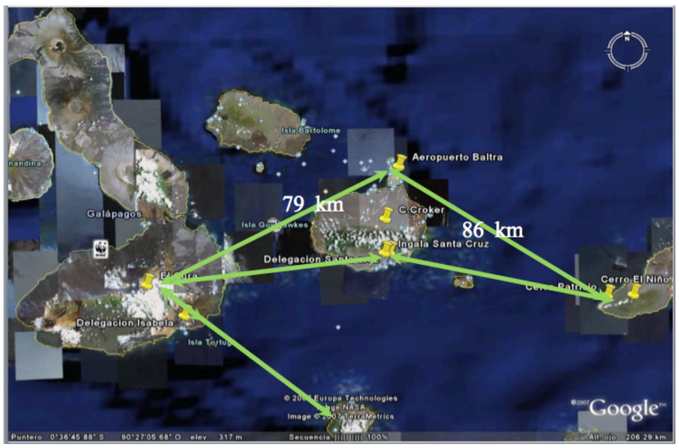

Figure 4. Peripheral links for the Galapagos Island wireless network, including the link to the island of Floreana, which does not have line of sight with Cerro Croker.

Satisfied that that the distance is not a problem, as long as the first Fresnel zone can be cleared, in 2007 we designed a solution to provide data connectivity to five islands on the Galapagos archipelago, with links in the 80 km range over the Pacific Ocean. The designed network was later implemented by a local contractor and is currently offering services to the communities there [14], [15]. Figure 3 is the central network stemming from Cerro Croker at 1800 m altitude.

A peripheral network (shown in figure 4) was added to increase reliability, so that each site was served by at least two completely independent links built taking advantage of the elevation provided by the existing volcanoes.

B. Malawi

The College of Medicine in Blantyre runs a Malaria prevention program jointly with the Hospital at Mangochi, and their need for an efficient telecommunications infrastructure prompted the ICTP to design and install a broadband wireless network, making use of Zomba Peak, as shown in figure 5.

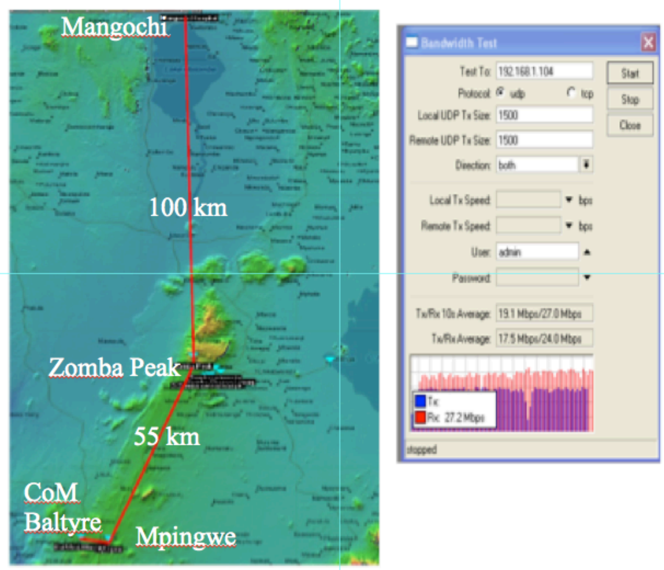

Figure 5. Wireless backbone from the College of Medicine (CoM) at Blantyre and the Mangochi Hospital, stretching over a portion of Lake Malawi. The end to end throughput is about 50 Mbit/s average, and the link from Zomba peak to Mangochi is 100 km.

Zomba Peak at 2000 m a.s.l. is an obvious choice for the role of base station to provide service to several health maintaing organizations in Zomba city as well as to serve as a repeater point to Mangochi, 100 km due north. Although reportedly previous attempts to link Zomba Peak with Mangochi were not successful, after the site survey we became confident that this link would work, and that the alternative of using two extra repeater points in Ulongwe and Ntaja was not needed. Since Zomba Peak is not visible from the College of Medicine in Blantyre, a repeater point was required in the hill of Mpingwe, 7 km east of CoM and 55 km south from Zomba peak.

C. *Urban high speed wireless links at the Sidi Mohamed Ben Abdellah University, Fez, Morocco*

The university of Fez in Morocco faces the need to provide connectivity to some of the remote sites, at distances of a few kilometers. They obtained NSRC assistance to improve their computer network by deploying high performing routers that serve several campuses and to install wireless links with throughput approaching 80 Mbit/s in March 2012.

D. *Lesotho*

UNDP (United Nations Development Program) [17] is executing the African Adaptation Program, a project to help several countries of the continent to meet the challenges posed by climatic changes. They have installed high performance computer centers that need to share data in order to build accurate prediction models. A team from the Telecommunications/ICT for Development Lab at ICTP went to Lesotho in July 2012 to train a group of local technicians in the installation of a broadband wireless network linking several institutions to the Lesotho Meteorological Center at speeds of the order of 40 Mbit/s. The hub is Mpilo, where a 45 m high wireless router provides coverage to the other organizations that need to share climate the data.

E. Micronesia

In August 2012 the Pacific Island Schools Connectivity, Education, and Solar (PISCES) Project [18], with assistance from local community members, installed a 15 km, solar-powered wireless Internet connection and an innovative computer lab at a primary school on the island of Udot in the state of Chuuk, Micronesia. Figure 9 shows the preparation of the pole to house both the wireless router and the photovoltaic system to power it. The link was a hands-on application of the training on Wireless networking and Solar Energy conducted at the University of Guam the previous week.

Figure 6. Some of the members of the PISCES project, aided by local volunteers, preparing the pole for the wireless link and photovoltaic system at the school of Udot, in the state of Chuuk, Micronesia.

V. CONCLUSIONS

We have presented some examples of wireless networks in which we were directly involved in recent years, to show the feasibility of its deployment by communities or local organizations independently from traditional telecom providers. We believe that these technologies can be a valuable part of the mix to provide a better telecommunication infrastructure in many places and have been conducting workshops and making available training materials to promote its use by anyone interested. Accordingly, we are planning a tutorial on the subject to be held at the IEEE Global Humanitarian Conference planned for October 2012 in Seattle, Oregon, and a two weeks long workshop in Bogota, Colombia, [19], in February 2013.

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